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Towards new Deltas





Cartoons taken from: 'Duurzaam leven aan de zee: De Nederlandse Kust in 2080' (Sustainable living alongside the sea: the Dutch Coastline in 2080). TNO report 2007.

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Towards new Deltas

For over a thousand years, people had little choice but to adapt themselves to the forces of nature. If the delta region where they lived flooded, they simply moved elsewhere. Over the last thousand years or so, people have progressively learned how to adapt such regions to their own needs, without realizing that - in doing so - they were interfering in the long-term processes involved in the very formation of such areas. It is only recently that we have begun to realize this. The time has come for a new approach: we can now develop plans for and structure deltas anew, step by step, while taking into consideration - and even making innovative use of - the natural substratum or ground layer. We can, for example, now ensure that our road and water (drinking water, agricultural water and industrial water) infrastructure networks can function more independently of the ground layer. The same may also be true of our residential and commercial buildings. If we succeed in this, the natural and dynamic interplay of forces in a delta - which lies at the basis of the beauty, biological diversity and productivity of such regions - will again be able to establish a natural and sustainable balance without causing us any significant problems.

In this article, we describe and discuss the situation in two comparable yet very different deltas: the delta region of the southwestern Netherlands and the delta of southern Louisiana in the USA.

Layer Model

The Layer Model is a conceptual model for the analysis, integrated design and planning of land use, water management and civil engineering works such as roads, waterways, and other works aimed at promoting safety and water management. This model was used in the Dutch policy memorandum '*Ruimte voor ontwikkeling*' (*Space for development*) (2005). It provides the insight needed for the parties concerned to work together in formulating regional delta development plans that are focused on the future, economically feasible and livable.

The model distinguishes three physical layers, each of which influences the spatial potential (including the environmental planning parameters) of the layer above it. Each layer is subject to change, but the pace of change differs per layer. The slower the pace and the larger the scale on which changes occurs, the more careful one must be in causing any such changes, as they will impact the future for a long time to come.

The first layer is the substratum or 'ground layer', which consists of the (sub)soil, groundwater and surface water as well as their associated flora and fauna. Changes

here occur naturally over a timescale measured in centuries (50 to 500 years), are generally large-scale in nature, and progress slowly but steadily. Human intervention in this layer has the potential of adversely affecting sustainability and of saddling future generations with the need to implement expensive and large-scale management activities.

The second layer consists of 'networks' i.e. all the visible as well as non-visible infrastructural networks including waterways, dikes, sluices, other water control works, roads, railroads, pipelines etc. Changes in this layer take place over a timescale of 25 to 100 years.

The third layer is the inhabited or 'occupied' layer established by the spatial patterns of human use and includes spaces for living, working and recreational activities. Changes here take place over a timescale of 10 to 25 years.

In addition to these three physical layers, the socio-economic & cultural dimension is also important. Managing change in all three layers in relation to the relevant social, economic and cultural aspects is perhaps the biggest challenge faced by environmental

planners. Managing and protecting the ground layer is critical for ensuring sustainability (ecology). The network layer is essential for ensuring functionality (the economy). Finally, management of the occupied layer is particularly important for ensuring social justice and equality (sociology).

The basic concept behind the Layer Model is that there is a large difference between the pace of change in the different layers and that the various layers influence each other. This difference in the pace of change determines the order in which land use plans are formulated. First, the impact on the 'ground' layer and the long-term natural processes involved must be adequately studied and planned. Only then is it possible to formulate plans and activities in the 'network' and 'occupied' layers which properly take the ground layer into account and even take optimum advantage of the specific characteristics of the ground layer.

Developments in a higher layer do not always automatically have to adapt to a lower layer, but one should at least be aware of the long-term consequences of the choices made before they are implemented.

In analyzing and designing developments, a great deal of attention should be paid to the characteristics and uses made of the ground layer and network layer and to the structural impact of both layers. After all, it is these layers that will largely determine the sustainability of future activities and developments and the associated management and maintenance costs for a 'livable' environment now and in the future.

The national, regional and local government bodies are responsible for structuring and managing the ground layer and the network layer. And it is these two bottom layers which determine what kind of environment will be available for the uppermost occupied layer.



Fig. 1

The layer-model. Source: www.ruimtexmilieu.nl

The advantages of using the Layer Model are that it:

- increases awareness of the complexity of the issues involved and provides an integrated perspective of the environment in which we live;
- provides insight into integrated solutions;
- provides insight into the various interests, actors and stakeholders involved;
- makes clear what scale is involved: national, regional or local;
- provides insight into the choices made.

Cooperation between Zeeland and Louisiana

Rijkswaterstaat (Dutch Directorate-General of Public Works and Water Management of the Ministry of Transport, Public Works and Water Management) and the United States Army Corps of Engineers (US equivalent of Rijkswaterstaat) have been working together since 2004. As a result of the flooding disaster that struck New

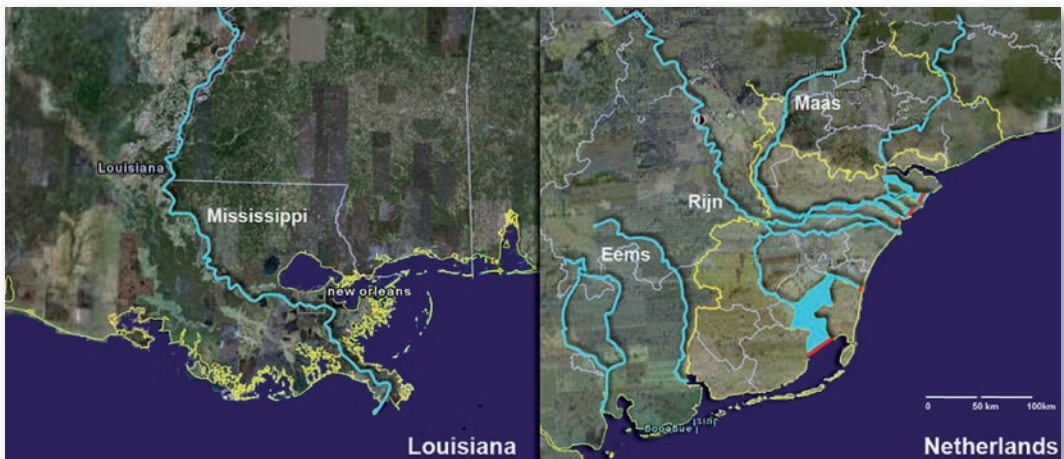


Fig. 2 Comparable Delta's. Source: Dick Kevelam, DHV

Orleans at the end of August 2005, this cooperation was intensified and the Dutch province of Zeeland also became involved. One consequence of this is that the Province of Zeeland and the State of Louisiana decided to cooperate on a substantive as well as administrative level. The delta region of the southwestern Netherlands actually has a great deal in common with the southern delta area of Louisiana. This is clearly illustrated by Fig. 2, in which the Netherlands is pictured upside down. Both regions have also suffered a major flooding catastrophe, in 1953 and 2005 respectively. Both deltas have been shaped by a combination of natural processes and human intervention. Finally, the inhabitants of both regions wish to enjoy sustainable development within a delta that will remain a safe place to live for a long time to come.

If we view the developments in the Mississippi Delta and the Rhine-Meuse-Schelde Delta from the perspective of the Layer Model, important lessons can be learned about managing rivers and deltas from the manner in which the inhabitants of both regions impacted the ground layer, consciously or unconsciously. Looking backwards,

this should of course come as no surprise, as civil engineering works and activities can greatly impact the ground layer and the natural processes responsible for land formation in such areas. The physical processes responsible for land formation include tidal action, (ground)water flows, sediment (sometimes polluted) transport, sedimentation, erosion, transport, and nutrient deposition. These abiotic processes are followed by biological processes, which in turn have an impact on land formation. Examples of this include: growth of vegetation in intertidal areas, which speeds up sedimentation and further growth; anaerobic conditions in deeper water layers caused by the sedimentation of organic material; large-scale development of toxic blue-green algae due to an oversupply of nutrients carried by the river into an artificial freshwater lake.

In both deltas, it is an ongoing challenge to protect the region from flooding as effectively as possible. However, with a bit of imagination, foresight and ingenuity, the natural ground layer and the natural processes at play in that layer can be taken ad-



*Fig. 3 Mississippi Birdfoot delta.
Source: Landsat 7, U.S. Geological Survey.*

vantage of within the framework of flood protection measures. It then becomes possible to 'get two for the price of one': to provide long-term safety from floods and at the same time ensure that the region can continue to function well from an ecological as well as water management perspective and can also serve as the basis for healthy economic development.

The Mississippi Delta

About two centuries ago, humans started intervening in the Mississippi Delta to prevent the river from flooding its banks. After the 1927 flood, newer and stronger dikes were built to ensure that the river remained fixed in its bed. 'Bypasses' were built to allow for extra water discharge in times of very high river discharges. River distributaries were blocked off to ensure adequate channel depth for shipping. The effect of all these interventions was a dramatic change in the flow of water and sediment.

Most of the river water and the suspended sand and silt no longer flowed sideways into the delta marshlands but was transported via the main river channel inside the dikes directly to the deep waters of the Gulf of Mexico. The result was the formation of the so-called Mississippi Birdfoot Delta, illustrated in Fig. 3.

In the absence of human intervention, the lower reaches of a river carve out a new channel as soon as the old riverbed becomes blocked by the accumulation of too much sediment. The river then simply finds a quicker path to the sea by breaking through the natural river embankment. After the main flow of the river has been diverted into

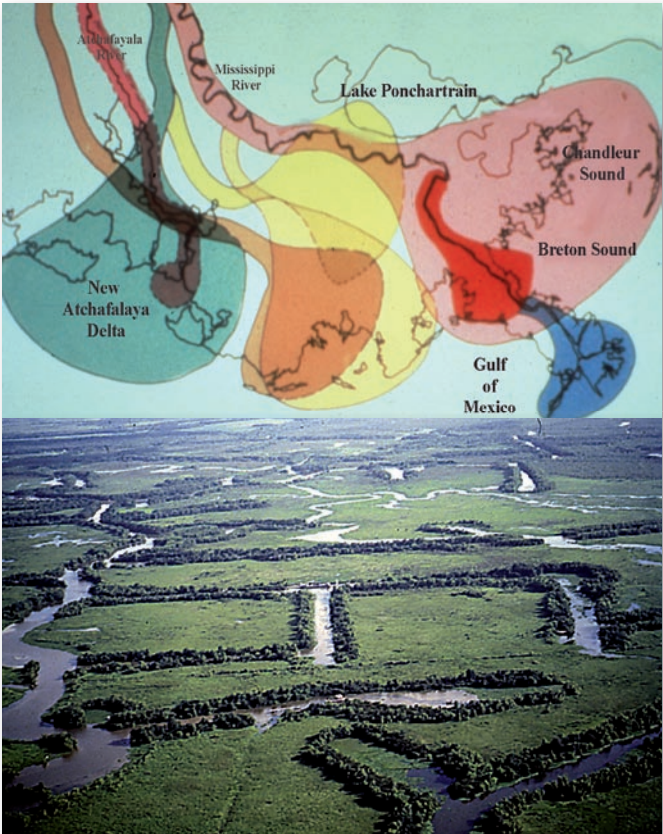


Fig. 4 Major Mississippi River Delta Lobes. Source: Kerry St. Pé, Barataria-Terrebonne National Estuary Program.

Fig. 5 Man-made changes in the way water moves through the system. Source: Kerry St. Pé, Barataria-Terrebonne National Estuary Program.

the new channel, the old 'delta lobe' develops into an area rich in biological diversity, influenced by the interplay of the sea and wetland formation. But in the long term, the ground level is lowered due to natural subsidence and erosion caused by the sea. After the finer sediments are eroded and washed away, the coarser particles that remain behind and accumulate lead to the formation of barrier islands in front of the area, with the remaining area becoming a shallow sea. The results of this process can clearly be seen in the area to the north of where the Mississippi presently flows into the sea. Over time, the entire process repeats itself and, in geological terms, is referred to as a Delta cycle. Fig. 4 shows the various delta lobes of the Mississippi.

The impact of human intervention on the inflow of fresh water and sediments to such areas and the excavation of a great many canals for the recovery of oil and shipping (see Fig. 5), in combination with subsidence and sea level rise, led to the accelerated erosion of saltwater and brackish wetland areas. This in turn accelerated the intrusion of salt water into freshwater cypress swamps, leading to the death of the trees and accelerated erosion under the influence of water currents and wind induced waves. At present, these processes are causing the disappearance of about 1 hectare of wetland per hour. Louisiana has a total of ca. 32,000 km² of wetlands, which is roughly the size



Fig. 6 Baldcypress forest in the freshwater swamps of the Mississippi delta



Fig. 7 Supply of sediment rich river water to closed off river arms. Source: Kerry St. Pé, Barataria-Terrebonne National Estuary Program.

of the Netherlands. These saltwater, brackish and freshwater wetlands play an important role in protecting the region from flooding caused by hurricanes. The freshwater cypress swamps in particular (see Fig. 6) absorb some of the impact of the waves and high water levels. One consequence of the accelerated erosion of the coastal wetlands is that the city of New Orleans, which was originally built on an elevated river dune location but has expanded into lower lying areas reclaimed from Lake Pontchartrain and protected by dikes, has become more vulnerable to flooding caused by hurricanes. Various small-scale wetland restoration projects have already been carried out. These involve restoring the flow of fresh water from the Mississippi River to the old river arms and raising the ground level of eroded wetland areas by spread. (see Fig. 7 and 8)

Flood protection and ecological restoration in the Mississippi Delta

Within the framework of its cooperation with Rijkswaterstaat, The United States Army Corps of Engineers asked the Netherlands for advice regarding the measures to be taken in Louisiana to increase the level of protection against flooding. In response, a consortium was formed within the framework of the Netherlands Water Partnership (NWP). The NWP is an umbrella organization within which government bodies, know-



Fig. 8 Restoration of eroded swamps. Source: Kerry St. Pé, Barataria-Terrebonne National Estuary Program.



Fig. 9 Pile dwelling.

ledge institutes, organized interest groups, and the business community have banded together with the aim of leveraging the expertise available in the Netherlands in the area of water management on a global scale.

The memorandum of advice, released in the second half of 2007, recommends - based on the lessons and experience gained in the Netherlands - a strategy referred to as the 'closed soft coastline.' This strategy is based on keeping the lines of coastal defense as short as possible while at the same time giving as much freedom as possible to the interplay of natural forces involved in the flow and transport of water, sediment and nutrients. The inherent potential of these natural processes to contribute to coastal

flood protection and to a sustainable ecosystem can then be leveraged to the full. This strategy can be symbolized (with thanks to Mindert de Vries from Deltares) by a fruit containing a hard pit, where the hard pit (symbolizing the city of New Orleans) is protected by the soft flesh of the fruit (symbolizing the coastal wetlands).

Risk analyses have been carried out to determine which level of flood protection can be justified in economic terms if one considers the required level of investment and the damage that can be prevented. A flood protection level of roughly 1/1000 is expected to be economically justifiable. This means that the flood protection measures taken would just barely be able to provide protection from a storm of a magnitude which occurs on average once every 1000 years. For purposes of comparison: the flood protection level adopted by the Dutch government for the southwestern delta region in the Province of Zeeland is 1/4000, and the protection level adopted for the Randstad (Dutch western urban agglomeration) is 1/10,000. The present protection level for New Orleans is 1/100.

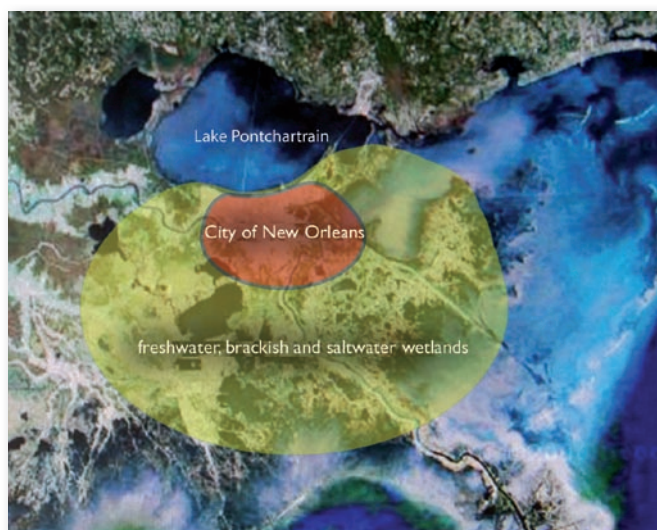


Fig. 10 Strategy of the "closed, but soft coast": New Orleans protected by dikes as a stone in sound and solid fruit flesh of coastal marshes.

Broadly speaking, adopting the strategy of the closed soft coastline means that the following measures would be taken. The urban areas of New Orleans would be protected by dikes (the hard pit), it would be possible to close off Lake Pontchartrain if storm floods are expected, and the coastal wetlands surrounding the city would be restored (the soft flesh of the fruit). (see Fig. 10)

The first measure means that robust dike rings which can withstand wave splashover would be built in combination with flood barriers in the shipping and drainage channels. The second measure would necessitate a system of dikes with two storm surge barriers in the narrow channels connecting Lake Pontchartrain with the Gulf of Mexico. This would make it possible to prevent large amounts of water from flowing into the lake under storm conditions. Under normal conditions, the storm surge barriers would be open. Restoration of the coastal wetlands would mean that large areas of freshwater, brackish and saltwater wetlands around the city would again be

able to play a vital role in flood protection by acting as a sponge and partially absorbing the impact of waves and floodwaters in case of storms. The wetlands suffering from erosion can be restored by ensuring that sediment-rich river water again flows through the wetlands as naturally as possible. Where necessary, canals excavated in the past can be partly filled in, and wetlands which have already suffered from excessive erosion can be restored to an appropriate level by bringing in extra sediment via pipelines. Where infrastructure for roads and railroads blocks the natural flow of water containing sediments and nutrients, culverts and other types of passageways can provide a solution. The restored wetlands will also provide a sustainable impulse for the economy and culture of the region, based on harvests from the coastal wetland areas and the shallow coastal waters (lobster, shrimp, oysters, alligators etc.).

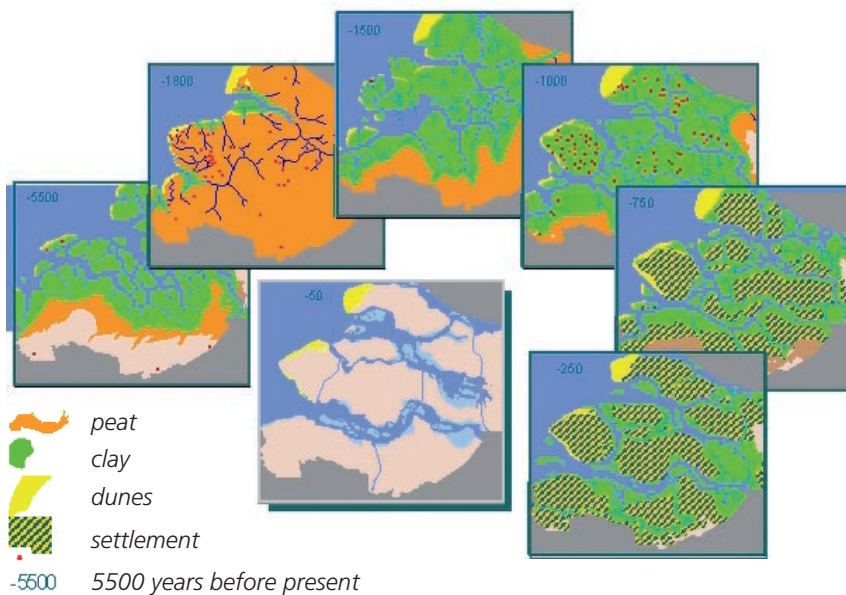


Fig. 11 Genesis of the Rhine-Meuse-Schelde Delta. Source: Delta 2003-5000 jaar terugblik, Peter Vos, TNO NITG, 2002.

In addition to the measures outlined above, it is important to set up an effective management organization. The wetlands can best be restored in a step-by-step process, whereby the steps taken are gradually scaled up on the basis of the ongoing experience and expertise acquired. It will be essential to effectively involve the residents and interest groups in the planning and design process. Without broad public support, it will be difficult to carry out the necessary measures.

Buildings located outside the protective rings of dikes will have to be adapted to deal with storm floods, for example by building on piles that are sufficiently elevated. This is already happening in some places. (see Fig. 9)

The Rhine-Maas-Schelde Delta

About a thousand years ago, the inhabitants of the Rhine-Maas-Schelde Delta first started taking measures aimed at influencing the ground layer. Until then, they did not have the techniques and the organizational ability to make much of an impact; all they could do was adapt to their surroundings. The forces of nature determined where they could live and what kind of work they could do. So people lived on the higher ground and cultivated crops there. Lower lying ground was used as pasture-land. And if sea level rise allowed the sea to break through the coastal chain of dunes, people simply made room for the sea and left - at least until natural processes of sedimentation and wetland formation eventually made new land available that was suitable for habitation.

At the beginning of the Common Era, there were many villages scattered throughout the Delta (see Fig. 11), but by 500 A.D. they had all disappeared because the sea had breached the protective chain of coastal sand dunes. Around 1000 A.D., a great many villages had again been established, particularly on Walcheren. Clearly, the network layer and the occupied layer adapted to the dynamic nature of the ground layer, since the inhabitants had no other choice.

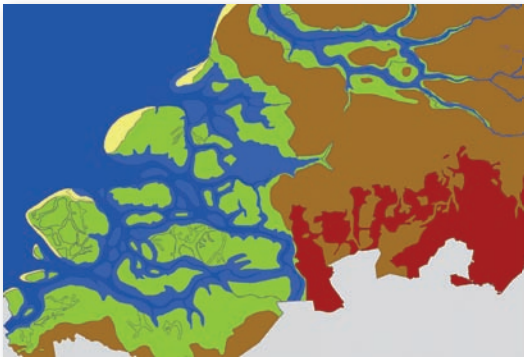


Fig. 12 Possible Delta area now, if we did not had started building dikes. Source: RISK in cooperation with les de Vries, Rijkswaterstaat, RIKZ, 2003.

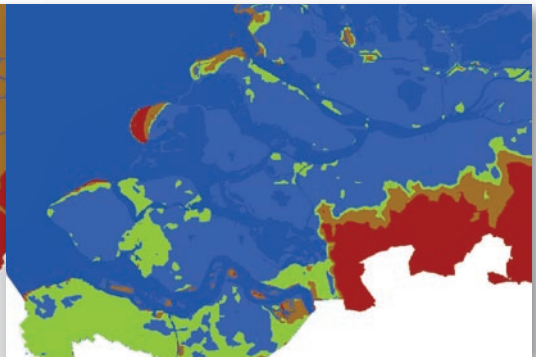


Fig. 13 Delta, if we should pull down our dikes now. Source: RISK in cooperation with les de Vries, Rijkswaterstaat, RIKZ, 2003.

Impoldering: reclaiming land from the sea

Around 1000 A.D., the situation changed: people began reclaiming land - in particular salt marshes and mud flats - from the sea, referred to as 'impoldering' in the Dutch situation. In other words, they began to influence the ground layer and control it. They built dikes and dug drainage canals to keep the new land dry. This was possible not only because they developed new techniques, but also because they learned to organize themselves more effectively. Such organizations were the predecessors of today's Water Boards.

The combination of dikes and a system of drainage canals in the newly reclaimed land, referred to as 'polders', provided the inhabitants with good farmland as well as protection from the sea. However, the impoldering activities also started an irreversi-

ble process of subsidence, whereby the ground level gradually sank lower over time. This was caused by the drainage activities on the one hand and by the elimination of the natural processes of sedimentation, which led to land formation, on the other. This can be demonstrated with the help of a computer model (see Fig. 12), which can be used to run a simulation of how the Delta would now look if impoldering had never taken place. Due to ongoing sedimentation processes, the Delta region would have 'risen' - keeping pace with the sea level rise - and would now consist largely of wetlands. But in reality we started the impoldering process roughly 1000 years ago, and if we were to remove the dikes now, most of the Delta region would find itself under water (see Fig. 13). The difference between these two Fig.s clearly shows the impact of human activity on the ground layer. This can be demonstrated not only by a computer model but also by the actual situation, in particular the contour map (see Fig. 14). The older a polder is, the lower it lies. The opposite is also true: wherever sedimentation processes were allowed free play, land accretion was able to continue.

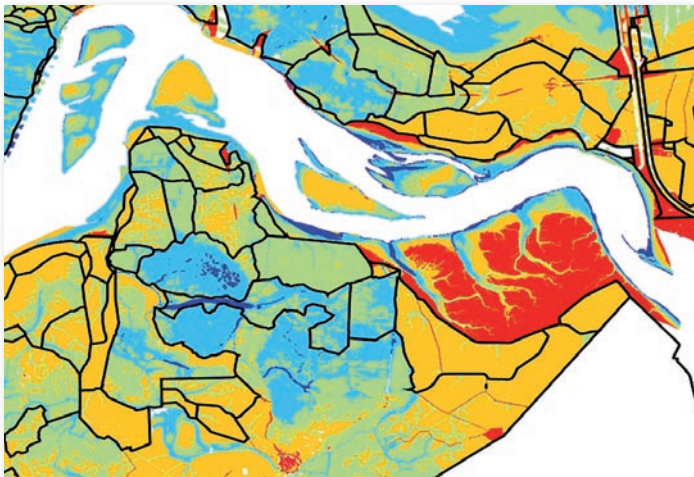


Fig. 14 Ground-level of a part of Zeeland. The Drowned Land of Saeftinghe (red coloured) as one of the highest parts of Zeeland.

Paradoxically, the 'Verdrongen Land van Saeftinghe' (Drowned Land of Saeftinghe) is now the highest part of Zeeland outside of the dunes.

The impoldering activities and resulting subsidence of the ground layer created a potentially dangerous situation. As long as the dikes held, everything was fine. But they didn't always hold. The technological capabilities of the inhabitants were not unlimited, and a combination of extreme weather conditions, spring tides and inadequate dikes regularly caused large and small floods. Table 1 provides an overview of major flood disasters. Clearly, the inhabitants did not always succeed in controlling the ground layer. The ground layer regularly 'struck back' and the Delta landscape is dotted everywhere with the scars of this ongoing battle: pools and creeks formed where the sea breached the dikes and many submerged villages. Sometimes, the inhabitants resigned themselves to having lost the submerged land to the sea, as in the case of the 'Verdrongen Land van Reimerswaal' (Drowned Land of Reimerswaal) and the island of Orissant. But in most cases, people returned to reclaim it anew. Apparently, the risk of new disasters was outweighed by the benefits of rich farmland.

838	The entire coastline of the provinces of Holland were flooded
1404	First St. Elizabeth's Flood
1421	Second St. Elizabeth's Flood
1530	St. Felix Disastrous Saturday
1570	All Saints Flood
1574	Provinces of Holland and Zeeland flooded
1682	161 Polders in Zeeland flooded
1808	Floods in Zeeland and Vlaanderen
1906	Large parts of Zeeland flooded
1916	Provinces of Zeeland and Noord-Holland flooded
1953	The Disaster

Tabel 1 Major flood disasters in the Rhine-Maas-Schelde Delta

The impoldering of the water

The most recent disaster took place in 1953. Due to a combination of spring tides, northwest storm, and overdue maintenance, the sea broke through the dikes in a great many places. As a result, 1836 people died and an enormous amount of damage was done. After the Disaster of 1953, the government decided to construct a marvel of engineering - the Delta Works - a feat which still draws a great many admiring visitors and delegations from all over the world.

Essentially, the plan consisted of raising and strengthening the dikes and dunes and shortening the coastline by over 700 km. The construction of the Maeslant flood barrier in the Nieuwe Waterweg (New Waterway) in 1997 marked the completion of the Delta Works. Before the construction of the Delta Works, the Southwestern Netherlands was an estuarine region. An estuary is an area of transition between the river and the sea where river water mixes with sea water - resulting in a gradual transition from fresh water to salt water - which is still subject to tidal influence. As a result of the Delta Works, the original estuary was transformed into a series of water basins physically separated from each other. Fresh water from the river and salt water from the sea were also kept strictly separated, and the influence of the river was no longer felt in most of the Delta. The only estuary that retained its character as such was the Westerschelde (Western Scheldt).

Like the impoldering activities, the Delta Works are an example of human intervention in the ground layer. As a result, the Delta waters are no longer subject to the dynamic natural processes that had previously been in play in the ground layer: ebb and flood tides, sedimentation and erosion, transitions from fresh water to salt water etc. One can also put it as follows: after the impoldering of the land, the Delta Works led to the impoldering of the water. This has provided the inhabitants with the necessary level of safety and also been a driver behind the economic development of this previously relatively isolated part of the Netherlands.

The Delta Works, particularly in their original form, were a prime example of the belief that man can control nature with the help of technology. It fits perfectly into the

postwar reconstruction period and the authoritarian concept of society prevalent at the time. To realize this, one has only to recall the voice of Philip Bloemendaal in the news broadcasts played in movie houses in the 1950s, or the resignation which characterized the fishermen forced to leave Veere after the Veerse Dam (first closure of an estuarine area within the framework of the Delta Works) was completed. But social beliefs and attitudes changed in the 1960s, and these changes also impacted the Delta Works. In the 1970s, an impassioned battle was fought between the established order on the one hand and the environmental movement together with the fishermen from Yerseke on the other. The result was a typical Dutch compromise: the storm surge barrier in the Oosterschelde (Eastern Scheldt), leaving the Oosterschelde not



Fig. 15 The Delta Works.

completely closed or completely open, but something in between. The storm surge barrier - the crown jewel of the Delta Works - is still a marvel of hydraulic engineering and human ingenuity to this day.

Drawbacks of the Delta Works

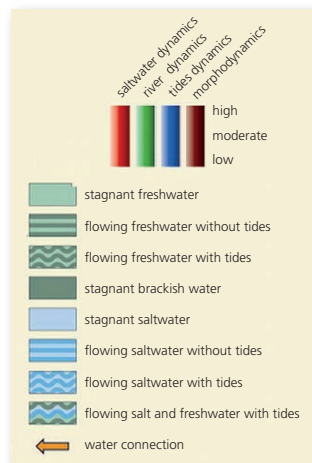
But over time, the proud image of the Delta Works began to suffer some erosion. It gradually became clear that, although this engineering marvel had brought safety to the region's inhabitants, various less welcome developments were taking

place. We began to wonder whether the impoldering of the Delta waters, which after all was a major intervention in the ground layer, had really been such an ideal solution.

As time passed, it became increasingly evident that elimination of the dynamic processes characteristic of an estuary (involving river and tidal flows, salinity gradients, morphology etc.) has ecological drawbacks. Lack of exercise and motion in people lead to blockage of the arteries. Similarly, eliminating or reducing the dynamic interplay inherent in an estuary also causes all kinds of unhealthy situations (see Fig. 16). Each of the Delta water basins suffers from problems that can be traced to the reduced flow of water containing sediments and nutrients through the basin. In the original estuarine situation, these nutrients – as they flowed from the river to the sea – were gradually converted into algae, zooplankton, bottom-dwelling invertebrates, and shellfish, which in turn served as food for populations of fish and birds. However, in a stagnant lake situation, excess nutrients lead to excessive (blue-green) algal blooms.

The negative effects of the Delta Works can be summarized as follows:

- The freshwater Volkerak-Zoommeer basin suffers from annual blue-green algal blooms (see Fig. 17).
- The same is true of the Binnenschelde, which borders the Volkerak-Zoommeer.
- The brackish lake referred to as the Veerse Meer has witnessed a massive development of sea lettuce and suffers from oxygen depletion in the deeper layers.
- As a result of reduced dynamics and water flow, polluted river sediments have been deposited in the freshwater Haringvliet and Hollands Diep basins, resulting in heavily polluted bottom layers. Fortunately, the quality of the river water has greatly improved in recent years and the quality of the sediments now being deposited is much better, but these accumulating sediments are becoming an increasingly serious problem for the discharge of river water.
- The saltwater Oosterschelde suffers from 'sand hunger'. The tidal channels are too large for the smaller quantities of water now flowing through the storm surge barrier in the entrance. The morphology of the basin is therefore being reshaped by natural processes to reach a new dynamic equilibrium. In the process, valuable areas of mud flats, salt marshes and shoals are disappearing and eroding as bottom sediments are redistributed to fill in the deeper channels. In addition, the biological productivity of the Oosterschelde has diminished over the last 10 years. This is thought to be caused primarily by a significant decrease in the transparency of the water layer, which in turn is probably caused by the release of humic acids from layers of peat subject to erosion.
- In the past, the saltwater lake referred to as the Grevelingenmeer suffered from oxygen depletion in the deeper layers. The construction of an opening through the Brouwersdam (the dam closing off the original channel to the sea) has partially restored the original situation, in which water is exchanged between the lake and the sea, and has therefore partly resolved this problem. Nevertheless, the Grevelingenmeer is still a fragile ecosystem in which the natural dynamics present are



insufficient to maintain a healthy balance, leading to oxygen depletion in the deeper layers. The data measured shows that water transparency in this system is also decreasing and that the bottom fauna is undergoing changes.

- In the Westerschelde estuary, intertidal areas have disappeared as a result of a great many activities involving impoldering and strengthening of dikes. Although this estuary has retained its character as an estuary, hundreds of hectares of intertidal areas have been sacrificed in the process. The successive rounds of dredging over the years aimed at increasing the navigable depth of the shipping channels have also contributed to these developments.

When viewed against the background of the centuries-old battle waged by the Dutch against the sea, the negative effects summarized above might very well be classified as 'collateral damage'. In actual fact, for quite some time the Delta Works were put on a pedestal in the Netherlands and criticism was simply not done. This perspective changed only gradually, as people slowly started taking a different approach to wa-

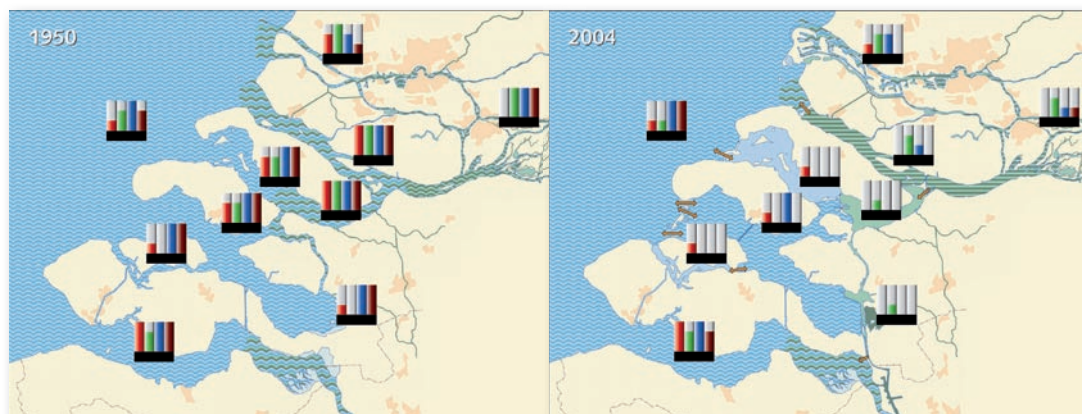


Fig. 16 The disappearance of estuarine dynamics caused by the Delta Works. Source: Achtergronddocument Kansenskaart Estuariene Dynamiek in de Delta, Rijkswaterstaat, RIKZ, 2005.

ter management - a change which started with the construction of the storm surge barrier. It involved a change from sector-focused to integrated water management. Instead of approaching an issue only in terms of safety, or agriculture or water quality, there was a shift to an approach that integrates all these aspects and more.

In the end, this integrated approach made it possible for people to realize and admit that the Delta Works actually suffered from shortcomings. In the 'Vierde Nota Waterhuishouding' (Fourth Memorandum on Water Management, 1998), a policy goal for the Delta is described that involves restoration and strengthening of the natural processes, emphasizing a greater degree of exchange and gradual transitions between the various separate water systems.

Towards a new Delta Plan

It looks as if the time is ripe for a new Delta Plan, one which provides benefits in terms of safety as well as ecology, in terms of the economy as well as the human factor often referred to as quality of life. The vision behind such an approach has already been formulated in *De Delta in Zicht* (*The Delta in Sight*), which has found broad acceptance and is presently being worked out further in the Delta Programme. The key is to adapt ourselves more to the ground layer rather than vice versa, to make better use of the water systems instead of fighting against them. In other words, we need to view the water not just as an enemy but also as a potential ally. But this is possible only



Fig. 17 Bluegreen algae in the Lake Volkerak-Zoom.



Fig. 18 Katse Heule: Connection between Lake Veere and the Oosterschelde. One of the culverts of 5.5 by 3 m. Mean daily exchange rate of maximum 40 m³/s.

if the water systems again become healthy. To accomplish this, we must remove the straitjacket we have imposed on the Delta waters by impoldering, so that the dynamic interplay of forces so characteristic of estuaries is again allowed to do its work freely and naturally.

The impoldering process has already been partly reversed for the Veerse Meer with the construction of the Katse Heule, an opening linking it to the Oosterschelde, with fantastic results. By utilizing the natural forces of tidal flows, it has been possible to greatly improve the water quality of the Veerse Meer. The Delta Works originally started by tackling the Veerse Meer. It is only fitting that this basin should also be the first

project to be tackled in the New Delta Plan (avant-la-lettre). See Fig. 18.

There are also plans for restoring the role of dynamic estuarine processes in the other Delta waters. In 2010, the Haringvliet sluice complex will be opened a bit to reintroduce a salinity gradient in the Haringvliet, thereby enabling migratory fish species to swim in and out. A study is presently being carried out aimed at finding a solution for the extreme blue-green algal blooms in the Volkerak-Zoommeer. The most probable outcome is that re-establishing a link with the Oosterschelde – which would raise the salinity and introduce a slight tidal influence – is the only way to solve this problem. For the Grevelingenmeer, re-establishing the links with the Oosterschelde and the North Sea is also being considered. In 2009, the siphon already present in the Grevelingendam will again be started up, thereby introducing a certain degree of exchange and dynamic interplay in the eastern section of the lake. A study is also being carried out into the possibility of creating a large controlled opening in the Brouwersdam, perhaps in combination with a tidal power station that would supply electricity to the islands of Goeree-Overflakkee and Schouwen-Duiveland. All these plans and ideas have one thing in common: they make use of natural forces to restore the water systems to a healthier state.

These natural forces can also be used to provide extra flood protection by encouraging sedimentation wherever possible, thereby encouraging the development of salt marshes which – in combination with dikes – can provide coastal protection. This concept has been integrated into the development plan for Perkpolder (see Fig. 19).

Taken together, these projects make it clear that we are increasingly turning our face towards the water instead of our back, and that we are looking towards the water not only as an enemy but also as a potential ally.

New approach requires adjustments

Restoring the natural interplay of forces and processes in the Delta waters will provide many benefits for the network layer and occupied layer. The inland shipping route between Rotterdam and Antwerp will be able to benefit from shorter waiting times at the locks. Recreational and residential activities near the water will benefit if the nuisance created by the odor of rotting blue-green algae is no longer an issue. Fisheries will benefit from ecologically healthy water basins with open links to the North Sea, and there will be increased opportunities for saltwater aquaculture. Last but not least, there will be a positive impact on the safety of the region: salt marshes will again be able to develop in front of the dikes, and in times of very heavy rainfall, it will be possible to store river water in the Delta basins, thereby lessening the pressure on areas near the lower reaches of the river by the cities of Dordrecht and Rotterdam.

But there are also a few thorns buried among the roses. Some forms of human activity in the occupied layer have benefited from the intervention in the ground layer, in particular due to the increased availability of fresh water for agricultural and residential use and the various facilities along the shoreline which are based upon a fixed water level. We will have to find a solution for these issues if we wish to undo some of the negative effects of past interventions. In the long run increasing saltwater intrusion caused by sea level rise and decreasing river discharges also forces us to look for alternatives for the traditional freshwater supply. One approach to the issue of ensuring adequate

freshwater supplies in a Delta where waters become more saline would be to make the supply of fresh water independent of the ground layer by transporting the fresh water via pipelines instead of via the increasingly saline main and regional water system. It would then be possible to irrigate land much more effectively and economically and to provide better guarantees for the supply of fresh water. If the commercial firms supplying tap water were to take responsibility in this area and do business directly with the consumers of fresh water, it would also become much easier to determine whether supplying fresh water in this way would be economically feasible or not. A major advantage of this new approach is that one would no longer need enormous quantities of fresh water to combat the intrusion of saline water from the sea into the main water system in the lower reaches of the river near Rotterdam and Dordrecht. But to gain social support for this approach, it will be essential to clearly explain the problems which need to be solved as well as the new opportunities that will be created by the modified organizational structure. This is the main challenge now facing all the parties involved in working together to formulate realistic plans for the restructuring process needed to realize a New Delta.

Synthesis

Many similarities as well as differences can be found between developments in the Mississippi Delta and in the Rhine-Maas-Schelde Delta. Historically, human intervention in the ground layer of the Mississippi Delta – consisting of river canalization for navigational purposes and the construction of canals for the oil industry – was based on economic motives. But this intervention has caused a safety problem. The ability of the wetlands to serve as a sponge or buffer and absorb the impact of floods has suffered greatly, and this has negatively affected the safety of New Orleans and the surrounding area.

In the Rhine-Maas-Schelde Delta, recent human intervention in the ground layer – the construction of the Delta Works – was actually based on considerations of safety. However, by radically altering the character of the water systems involved, this intervention has led to ecological and economic problems. The natural and economic value of the region in terms of sustainability has therefore been negatively impacted, while at the same time the region is playing an increasingly important role as a buffer where recreational and other activities can still take place that are no longer possible in the surrounding urban agglomerations.

In both Delta areas, human intervention in the ground layer has gone too far and negatively impacted the network layer and the occupied layer. Alternatively, we can say that past interventions have focused too much on a single aspect to the exclusion of other aspects. In other words, the approach taken was a single-sector approach instead of an integrated one. This is perhaps the most important lesson we can learn from developments in the Mississippi Delta and the Rhine-Maas-Schelde Delta.

Historically speaking, three different phases can be distinguished in human activity with regard to deltas. In the initial phase, humans are more or less powerless and live at the mercy of the natural forces playing out in the ground layer. People simply have to adapt. In the second phase, we have developed the technological and organizational ability to adapt the ground layer to our own needs. However, we still do not

understand what the long-term effects of our intervention will be and, in the end, we have to deal with unexpected setbacks in the ground layer. We now stand at the beginning of the third phase, in which we know that we can do almost anything but also understand that we need to take better account of the natural processes and forces in the ground layer.

If you have the power to do almost anything, you are also confronted with the need to choose – to choose between striving for control over everything or allowing more space for natural processes to play out. The latter does not mean ‘surrendering’ to the forces of nature. It means entering into a dialogue with nature, as it were, in order to create a situation in which there is also sufficient space for natural processes – not only in the interest of nature itself but also in the interest of human society. In such a



Fig. 19 Multifunctional coastal zone for Perkpolder. Part of the Interreg IIIb Northsea Project ComCoast (Combined functions in coastal defence zones). Source: Buro Lubbers en Rijnbouwt Van der Vossen Rijnbouwt, in charge of AM and Rabo Vastgoed, in cooperation with the involved authorities: the local government of Hulst, the province of Zeeland, Rijkswaterstaat and the water board of Zeeuws Vlaanderen.

situation, it might even be possible to create a society which can function effectively without total control over the ground layer, a society in which the occupied layer and the network layer - when necessary - can even be separated from the ground layer. Possible examples include floating cities, floating roads, and a freshwater supply system that functions independently of the surrounding water systems. At the same

time, such a new situation would also allow us to derive greater benefits from the ground layer in the form of increased opportunities for saltwater aquaculture and greater protection from the sea based on natural processes such as sedimentation and transport of sand in the coastal zone ('sand rivers').

The challenge we now face in terms of the deltas of the world is an exciting one. We now have the insight and technological capability to establish sustainable deltas – sustainable in an ecological, economic and social sense. Of course, we are a far cry from knowing everything, but if we take one step at a time and learn from our previous steps, we can take up this new challenge and mark out a future path to the New Deltas!

Fig. 20 Ragworms farm Topsy Baits along the shores of the Oosterschelde and a floating house in Middelburg. Source: Kees Bos.



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